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WORKSHOP ON THE MARTIAN NORTHERN PLAINS: SEDIMENTOLOGICAL, PERIGLACIAL, AND PALEOCLIMATIC EVOLUTION

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WORKSHOP ON
THE MARTIAN NORTHERN PLAINS:
SEDIMENTOLOGICAL, PERIGLACIAL,
AND PALEOCLIMATIC EVOLUTION

Edited by

J. S. Kargel, T. J. Parker, and J. M. Moore

Held at
Fairbanks, Alaska

August 12–13, 1993

Sponsored by
MSATT Study Group
Lunar and Planetary Institute
University of Alaska

Lunar and Planetary Institute 3600 Bay Area Boulevard Houston TX 77058-1113

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Preface

The penultimate meeting in the Mars Surface and Atmosphere Through Time (MSATT) series of workshops was held on the campus of the University of Alaska in Fairbanks, Alaska, August 12 and 13, 1993. This meeting, entitled "The Martian Northern Plains: Sedimentological, Periglacial, and Paleoclimatic Evolution," hosted by the Geophysical Institute at the University of Alaska, was designed to help foster an exchange of ideas among researchers of the Mars science community and the terrestrial glacial and periglacial science community. The technical sessions of the workshop were complemented by field trips to the Alaska Range and to the Fairbanks area and a low-altitude chartered overflight to the Arctic Costal Plain, so that, including these trips, the meeting lasted from August 9 to August 14, 1993. The meeting, field trips, and overflight were organized and partially funded by the Lunar and Planetary Institute and the MSATT Study Group. The major share of logistical support was provided by the Publications and Program Services Department of the Lunar and Planetary Institute. The workshop site was selected to allow easy access to field exposures of active glaciers and glacial and periglacial landforms. In all, 25 scientists attended the workshop, 24 scientists (plus 4 guests and the meeting coordinator) participated in the field trips, and 18 took part in the overflight. The field trips and overflight were led by Troy Péwé, James Begét, Richard Reger, and David Hopkins. This meeting reaffirmed the value of expertly led geologic field trips conducted in association with topical workshops.

Program

Monday, August 9, 1992

6:30–6:40 p.m.

Welcoming Remarks
J. S. Kargel

6:40–6:45 p.m.

Field Trip Logistics
L. Simmons

6:45–7:30 p.m.

Science Objectives of the Field Trip
T. L. Péwé

Tuesday, August 10, 1993–Wednesday, August 11, 1993

FIELD TRIP I—ALASKA RANGE

Thursday, August 12, 1993

8:45 a.m.–12:00 noon

Workshop, Geophysical Institute
GLACIAL AND PERIGLACIAL GEOMORPHOLOGY OF ALASKA
Chair: J. M. Moore

Review of the Origin of Ground Ice on Earth
T. L. Péwé

Milankovitch Insolation Forcing and Cyclic Formation of Large-scale Glacial, Fluvial, and Eolian Landforms in Central Alaska
J. E. Begét

Cryoplanation Terraces of Interior and Western Alaska
R. D. Reger

Calderas Produced by Hydromagmatic Eruptions Through Permafrost in Northwest Alaska
J. E. Begét

OVERVIEW OF THE NORTHERN PLAINS
Chair: T. J. Parker

Stratigraphy of the Martian Northern Plains
K. L.Tanaka

Observed Climatic Activity Pertaining to the Evolution of the Northern Plains
L. J. Martin

The Distribution of Ground Ice on Mars
M. T. Mellon and B. M. Jakosky

Geomorphic Evidence for an Eolian Contribution to the Formation of the Martian Northern Plains
J. R. Zimbelman

Morphologic and Morphometric Studies of Impact Craters in the Northern Plains of Mars
N. G. Barlow

Ice in the Northern Plains: Relic of a Frozen Ocean?
B. K. Lucchitta

Friday, August 13, 1993

8:15 a.m.–12:00 noon

MODELS OF LANDFORM EVOLUTION IN THE NORTHERN PLAINS
Chair: J. M. Moore

Seismic-Triggering History of the Catastrophic Outflows in the Chryse Region of Mars
K. L. Tanaka and S. M. Clifford

Evidence for an Ice Sheet/Frozen Lake in Utopia Planitia, Mars
M .G. Chapman

Possible Occurrence and Origin of Massive Ice in Utopia Planitia
J. S. Kargel and F. M. Costard

The Thumbprint Terrain: What Will Mars Observer Tell Us?
M. W. Schaefer

A Model for the Origin of Martian Polygonal Terrain
G. E. McGill

A Formational Model for the Polygonal Terrains of Mars: Taking a "Crack" at the Genesis of the Martian Polygons
M. L. Wenrich and P. R. Christensen

Balloon Exploration of the Northern Plains of Mars Near and North of the Viking 2 Lander Site
F. R. West

HYDROLOGIC MODELS AND PROCESSES
IN THE NORTHERN PLAINS
Chair: J. S. Kargel

A Wet Geology and Cold Climate Mars Model: Punctuation of a Slow Dynamic Approach to Equilibrium
J. S. Kargel

Role of Groundwater in Forming Periglacial Features on Mars
A. D. Howard

West Deuteronilus Mensae Revisited: Can Near Be Extrapolated To(o) Far?
T. Parker

The Marine Sedimentary Model for the Evolution of the Northern Plains
T. Parker and D. Gorsline

Hydrological Consequences of Ponded Water on Mars
V. R. Baker

Summary and Discussion

Field Trip and Overflight Logistics
L. Simmons

Saturday, August 14, 1993

FIELD TRIP II—FAIRBANKS AREA

Sunday, August 15, 1993

OVERFLIGHT TO BARROW

Contents

Summary of Technical Sessions

The Northern Plains workshop, including associated field trips, took place August 9–15, 1993, in Alaska. The meeting was most notable for its field setting and for the fact that it brought together researchers from the planetary and Earth science communities who have special interests in cold-climate processes and landforms. Many of the planetary scientists who attended the meeting had never before observed periglacial and glacial ice in a field setting.

Program agenda follow this summary. The week-long program included the following major elements:

Monday, August 9, evening: Welcome and briefing for field trip I at the Geophysical Institute, University of Alaska, Fairbanks.

Tuesday, August 10–Wednesday, August 11: Field trip I to the Alaska Range, including overnight stay in Paxson.

Thursday, August 12–Friday, August 13: Workshop at the Geophysical Institute, including a Friday evening informal discussion session.

Saturday, August 14: Field trip II in the Fairbanks area.

Sunday, August 15: Overflight to the Brooks Range, Barrow, and the Arctic Coastal Plain, including a three-hour field trip in the Barrow area.

The primary purpose of the workshop's topical sessions was to summarize knowledge of the northern plains of Mars, to present new ideas on the possible evolution of the northern plains, and to hear presentations on terrestrial cold-climate processes and landforms. Most of the content of the formal presentations is in the abstracts (Part 1 of this report) and will not be repeated in this summary. A highlight of the lecture-hall sessions was an informal, two-hour discussion on Friday evening, August 13. The most lasting impressions for many participants were from the field trips and overflight. The weather was far from ideal, but it did not prevent key observations. Figure 1 shows the routes of field trip I and the overflight. A description of the field trips and overflights follows the synopsis of the Friday evening discussion, below. A slide set is being prepared to complement this written summary and will be published separately by the Lunar and Planetary Institute.

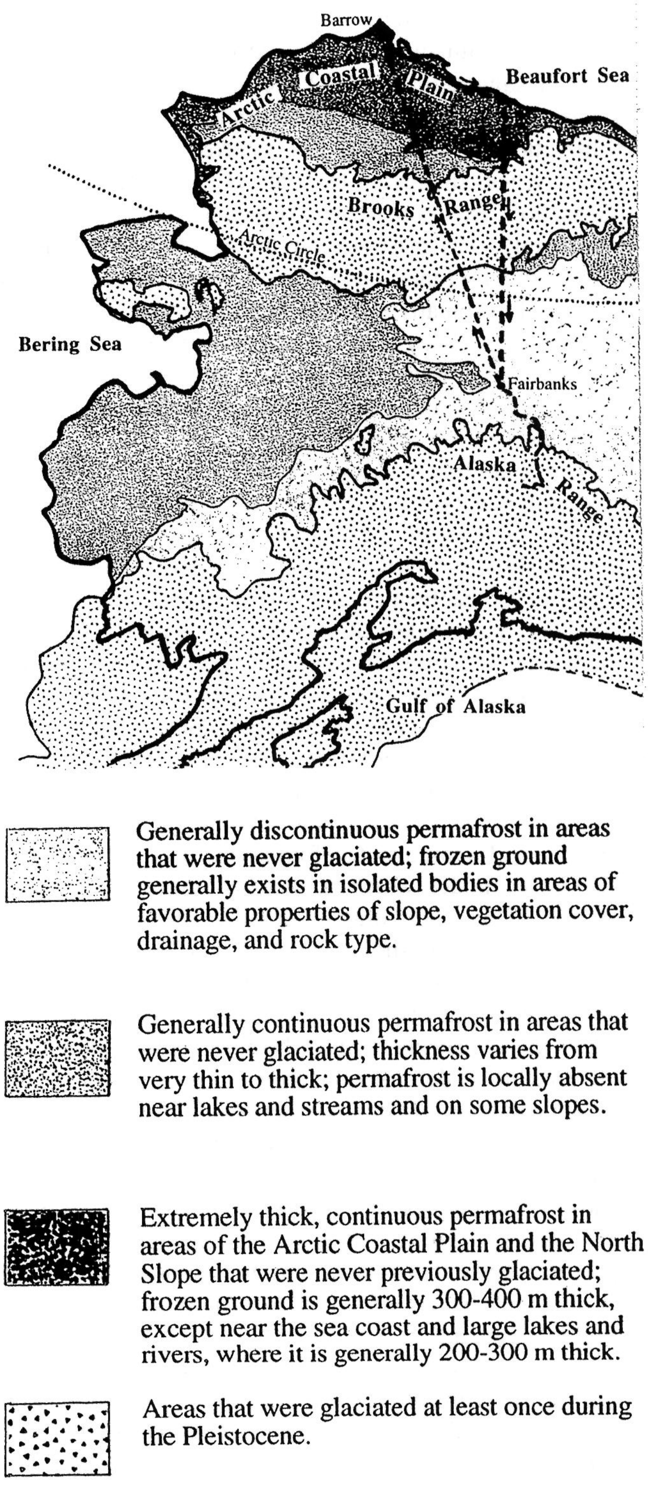

Fig. 1. Map of Alaska showing the routes of field trip I and the overflight and the limit of Pleistocene glaciation (from [1]), and the approximate present boundaries of continuous and discontinuous permafrost in areas that have not been glaciated (from [2]).

SYNOPSIS OF THE DISCUSSION OF FRIDAY EVENING, AUGUST 13, 1993

During the informal session, four invited specialists (T. Péwé, J. Begét, R. Reger, and D. Hopkins) in cold-climate processes and landforms presented their opinions on what they had heard during the formal presentations. Several presenters brought to the discussion small selections of Mars slides that had engendered controversy. The discussion centered mainly on possible periglacial and glacial processes and landforms in the northern plains of Mars.

Referring to the slides presented by the Mars scientists, Péwé asked his colleagues, "Has anyone seen a pingo?" The response at first seemed to be a flat "no," although Reger later spoke of linear pingoes and other pingolike forms on Mars as reasonable possibilities.

The cold-climate specialists had a unanimously favorable view of suggestions by B. Lucchitta and others that rock glaciers exist in the northern plains and fretted terrain, and that solifluction or gelifluction has occurred there. Reger, particularly, was impressed by some of the evidence for periglacial flow. However, Reger, like members of the Mars science community, was frustrated by the absence of virtually all groundtruth for Mars. The major differences of scale between terrestrial and putative martian rock glaciers were pointed out, but this discrepancy does not necessarily discredit the rock-glacier interpretation: It was noted that physics should not limit the size of rock glaciers, and long periods of time were available for their development.

The cold-climate specialists were intrigued by the large-scale polygonal terrains on Mars. They, like the Mars science community in recent years, did not accept previous ideas that large-scale polygonal terrains might consist of ice-wedge polygons or any other feature caused by thermal contraction cracking. Too many orders of magnitude of scale separate these martian terrains from ice-wedge polygons on Earth, and high-amplitude thermal waves cannot penetrate deep enough in the short times necessary to cause brittle failure and thereby cause cracks of the observed scale. The cold-climate specialists accepted as reasonable possibilities the models of G. McGill and M. Wenrich on the formation of these terrains by sediment loading and subsequent deformation. Péwé suggested an alternative model, which he sketched during the discussion session. This model draws a possible analogy between the martian cracks and similar cracks that he studied in the alluvium-filled desert basins near Phoenix, Arizona. All three models relate the origin of the cracks to deformation of sediments that overlie an irregular bedrock surface, although the mechanisms of deformation differ.

A distinction must be drawn between the well-known large-scale polygonal terrains that were the topic of discussion and the small-scale polygonal terrains that Lucchitta, T. Parker, and others have discussed in their publications as more reasonable analogs of ice-wedge polygons. The small-scale martian polygons have scales comparable to the ubiquitous polygons on the Arctic Coastal Plain of Alaska, as observed by overflight participants.

Although previous researchers interpreted the Viking landing sites in terms of eolian modification of volcanic terrains under arid conditions (the Mojave Desert has been cited as a specific analog), Péwé remarked during the evening discussion that the Viking 2 landing site "looks just like Antarctica," consistent with J. Kargel's suggestion that the Viking 2 landing site could be a moraine. Particularly, the rock-size distribution at the boulder-strewn landing site resembles ice-free (but formerly glaciated) areas of that continent. There was general agreement about the possible existence of a ventifact in a lander image. This finding was of interest to field trip participants because at one stop they collected wind-blasted ventifacts from the upper surface of a moraine. The cold-climate specialists accepted suggestions that the troughs observed at the Viking 2 landing site might be thermal contraction cracks, filled with sand wedges or ice wedges.

All four cold-climate specialists accepted, as a reasonable interpretation, a moraine analog of certain types of "thumbprint terrain," notably that in southwestern Utopia Planitia. But M. Schaefer pointed out that not all so-called thumbprint terrain was necessarily formed by the same or similar processes. Hopkins was especially skeptical of suggestions that the thumbprint terrain of Isidis Planitia might consist of moraines. Péwé accepted the possible De Geer moraine analogy for thumbprint terrain, as suggested by Kargel, but this analogy was not acceptable to Begét and Reger because of inconsistencies of scale. Begét pointed out that recessional moraines in the plains of central North America are more analogous in scale and form. Péwé and Begét accepted Kargel's interpretation that sinuous troughs and medial ridges in Arcadia Planitia and Utopia Planitia could be tunnel channels and eskers; Hopkins thought that some of the proposed tunnel channels were too sinuous.

The cold-climate specialists agreed with analogies by M. Chapman between subglacial volcanic landforms in Iceland, such as table mountains and moberg ridges, and features near the Elysium Plateau in the northern plains. These analogs were cited as supporting glacial interpretations of other features in the northern plains.

It was not clear whether the cold-climate specialists had developed a general consensus that glacial or periglacial processes had been active on Mars. Therefore, V. Gulick asked, "If you *had* to venture a guess (without betting your life on it) as to whether glaciation or periglacial processes had ever occurred on Mars, what would you say?" She stressed that specific interpretations of specific features were not the point of her question. Rather, her question was to address the terrestrial experts' overall impressions of the glacial and periglacial hypotheses. Péwé, Begét, Hopkins, and Reger responded as follows.

Péwé generally accepted evidence and hypotheses that Mars was glaciated and that periglacial processes had operated on Mars in the past, although he pointed out differences of scale between many martian features and their supposed terrestrial analogs.

Begét characterized the glacial hypothesis as "a perfectly reasonable hypothesis worthy of further investigation," and he agreed that periglacial processes have probably occurred on Mars. Begét stressed that the strength of these ideas was that several types of putative glacial and periglacial features on Mars occur in reasonably close spatial associations (temporal associations of these features are still not too well docu-

mented), and that these terrains look like some landscapes on Earth that have been shaped by glacial and periglacial activity.

Hopkins was hesitant to commit himself in favor of or against the idea of glaciation on Mars, but he was more supportive of the idea of periglacial processes.

Reger was favorably inclined toward much of the evidence that was presented for periglacial processes, but he was more reserved about glaciation. Particularly, he noted that he had not been presented with good evidence for glacial scour in the northern plains, an aspect that R. Craddock also pointed out.

The discussion by the terrestrial cold-climate specialists may be summarized as a unanimous "yes" on periglacial processes in general, mixed "yes" and "no" on specific periglacial interpretations of specific features, mixed "yes" and "maybe" on glaciation in general, and mixed "yes" and "no" on specific glacial interpretations of specific features. Thus, the collective conclusions of the cold-climate specialists were similar to those of a large segment of the Mars science community; we will have to touch the martian surface and kick a few rocks, so to speak, or at least we must obtain very-high-resolution images and topographic data of key areas before we can expect to reach definite conclusions; in the meantime, there are many hypotheses worthy of ongoing study.

The results of this discussion included some fresh perspectives on the evolution of the northern plains and on martian geomorphology, and they offered specific directions for possible future research. The discussion also provided a renewed interaction between the terrestrial and Mars science communities and the promise that this interaction will continue. Probably the greatest deficiency of the evening session was that possible marine and lacustrine processes and landforms, such as advocated in recent years by Parker, D. Scott, and other colleagues were not discussed at any length; several participants felt that these subjects should be discussed at future meetings.

SYNOPSIS OF FIELD TRIP I TO THE ALASKA RANGE, AUGUST 10–11, 1993

Field trip I, planned and led by T. Péwé, R. Reger, and J. Begét, covered part of the route along the Richardson and Denali Highways as described in the field trip guidebook [3]. The following description is keyed to those localities described in the guidebook where we stopped. The only description beyond that in the guidebook pertains to our group's particular experiences.

Tuesday, August 10: Drove on Richardson Highway southeastward from Fairbanks, alongside Tanana River, which receives mostly glacial outwash from the Alaska Range.

Stop 1. Harding Lake.

Stop 3. Tanana River overlook.

Stop 8. Delta-age (middle to late Quaternary) terminal moraine and outwash on Jack Warren Road. This glacial landscape shows the combined effects of glacial, glaciofluvial, and eolian processes. Participants collected ventifacts, which were shaped and polished by sandblasting cobbles at the top of this outwash deposit during a very dry and cold period shortly after glaciers receded. The outwash was later capped by ~1 m of loess.

Stop 9. Overlook from the Federal Aviation Administration station, milepost 262.7. Although clouds obscured what could have been a panoramic view of the Alaska Range, we could see clearly the terminal moraine of the Donnelly glaciation (late Wisconsin, about 20,000–30,000 yr old).

Stop 11. Edge of Delta-age moraine and overlook of outwash and Donnelly moraine.

Stop 12. Polygons, ice-wedge casts, and tundra vegetation.

Stop 14. Pipeline crossing and view of Donnelly-age moraine with kettles.

Stop, milepost 237.5. Overlook of braided Delta River. The river plain has been a principal source of loess for the Fairbanks area at least since the Delta glaciation. The far wall of the Delta River valley and the adjoining uplands show evidence for (1) the early Delta glaciation, which capped the uplands and filled all nearby valleys with ice; (2) the later Donnelly glaciation, which filled the Delta River Valley and incised it deeper without affecting the unglaciated uplands in this area; and (3) Holocene fluvial erosion of the wall of the Delta River valley. The uplands adjoining the Delta River Valley were ice free during the Donnelly glaciation, and therefore these uplands preserve the older, Delta-age glacial erosional surface. Postglacial erosion during the Holocene is represented by a gully and an associated alluvial fan on the far bank of the Delta River.

Stop 15. Black Rapids Glacier overlook.

Stop, milepost 217. Dead ice (ice-cored moraine) left by a Holocene advance of the Castner glacier. Field trip participants witnessed active thermokarst-forming processes here. Photos of the assembled field group and field trip leaders were taken (Figs. 2 and 3).

Stop 16. Trans-Alaska Pipeline.

Stop for night, Paxson Lodge (Paxson, Alaska).

Wednesday, August 11: Drove west from Paxson along Denali Highway along ice-contact crevasse fill and ice-marginal drainages.

Stop, milepost 7. Seven-Mile Lake. Many ice stagnation landforms related to Donnelly glaciation. Also stopped and photographed a discontinuous, segmented esker in a tunnel channel.

Stop 22, milepost 20.4. Stop at Tangle Lakes along an esker that is visible in Landsat images. Observed a sediment fan that was constructed at the terminus of a small channel. The channel was eroded by the outflow from a lake, formerly 16 m deep, that ruptured and spilled through an esker dam.

Stop 23. Roadcut in small esker. Group hiked across the crest and sides of the esker.

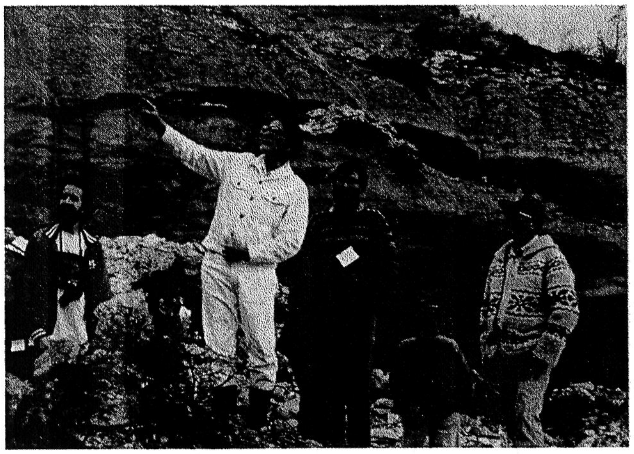

Fig. 2. Leaders of field trip I, T. Péwé (left of center, with MacArthur-like stance), J. Begét (center), and R. Reger (right, with baseball cap). M. Mellon, left, and N. Barlow at a distance in lower right. Background shows the stagnant, thermokarstic deposits of the ice-cored moraine left by a recent advance of the Castner Glacier (Alaska Range) probably more than 143 yr ago, probably less than 200 yr ago.

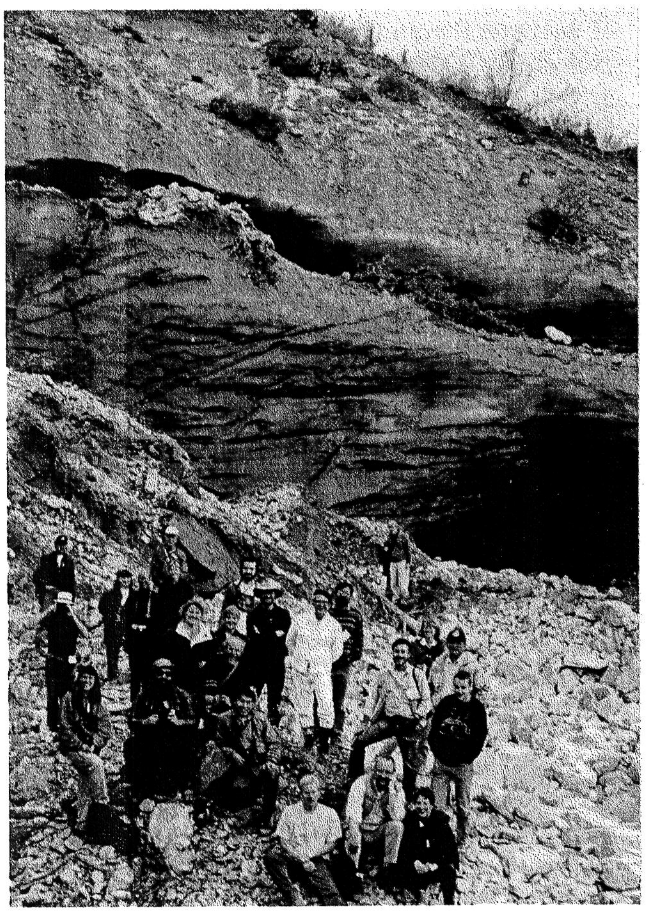

Fig. 3. Field trip I participants. Background is about the same as shown in Fig. 2. From front to back and left to right, participants are as follows: front row: J. Kargel, V. Baker, P. Baker; second row: M. Wenrich, T. Parker, K. Tanaka, B. Schuraytz, T. Baker; third row: F. West, B. Lucchitta, V. Gulick, M. Schaefer, J. Moore, J. Zimbelman, T. Péwé, J. Begét, M. Chapman, R. Reger; fourth row: R. Craddock, N. Barlow, G. McGill, C. Stoker, M. Mellon, A. Howard.

Stop 24. Whistler Ridge cryoplanation terrace.

Stop, milepost 32.2. Frost-sorted stone polygons, circles, and stripes on floors of kettles formed in a moraine of a piedmont glacier of the Denali glaciation.

Stop, milepost 32.5. Road cut through rock-glacier rubble.

Stop, milepost 36.6. Overview of Crazy Notch and ice-stagnation landscape in Maclaren River valley, which included a transverse esker, kettles, a large, flat-topped, terraced kame, and many palsas. Then we returned to Fairbanks on the Richardson Highway, making the following stops.

Stops at two overlooks of Gulkana Glacier.

Stop, near milepost 207. Rock glacier and talus slopes of Rainbow Mountain.

SYNOPSIS OF FIELD TRIP II IN THE FAIRBANKS AREA, AUGUST 14, 1993

This field trip focused on permafrost, periglacial landforms, frozen loess deposits, and construction that faces special engineering problems pertaining to the periglacial environment. Some of the stops are described in more detail by [4].

Stop 1. University of Alaska (Fairbanks campus). Discussion of the deposition of the Wisconsin Fairbanks loess, which is thought to include the oldest loess on Earth.

Stop 2 (described by [4], pp. 36–43). Walk to old agricultural field, now forested thermokarst mounds.

Stop 3. New golf course along Farmer's Loop Road near intersection with Ballaine Road. Péwé predicts that in two or three years it will be an area of evolving thermokarst.

Stop 4. Abandoned house, collapsing over thawing permafrost, along Farmer's Loop Road.

Stop 5. Stop near Alyeska pipeline along mining cut.

Stop 6. Road cut through Fairbanks Loess.

Stop 7. Big Eldorado Creek permafrost and peat bog. Depths to ice at two locations, just 3 m apart, were 50 and 70 cm. Creek forms icings 5–10 m thick during winter. Spruce are stunted ("elf spruce") due to thin active layer and harsh conditions.

Stop 8. Thermokarst pits in grassy meadow.

Stop 9. Thawing ice wedge beneath Trice Avenue.

Stop 10. Musk ox research farm.

Stop 11 (after lunch). Loess cliff, including thin (~1 cm) "Pa tephra" layer, along Highway 3, near the Sheep Creek Extension highway.

Stop 12. Wiggers' gold mine. Mining operation has cut into thick Wisconsin loess deposits that contain fossils of reindeer, caribou, extinct bison (*Bison priscus*), musk oxen, beaver, and mammoth. Ice-wedge ice occurs near the top of the mine cut; part of an ice wedge had toppled down, allowing us to examine it closely.

OVERFLIGHT TO BARROW AND GROUND EXCURSION NEAR BARROW, AUGUST 15, 1993

The aircraft was a 19-passenger, high-wing Casa. Wheels up in Fairbanks occurred at 7:21 a.m. The sky was heavily overcast throughout the flight except for the last part of our return journey. During the leg to Barrow, the aircraft generally stayed above the cloud ceiling, preventing a view of the ground. Participants stopped in Barrow for about four hours and engaged in a brief field excursion led by D. Hopkins. From the ground we observed sea ice on the beach, walked over thawing ice-wedge polygons, examined fresh frost (thermal contraction) cracks in the tundra, and photographed shallow thaw lakes and their low shoreline bluffs.

The return flight took us east just slightly landward of the coast almost to Deadhorse (near Prudhoe Bay), and from there south to Fairbanks. On the first leg, from Barrow to the Deadhorse area, we flew beneath a 600' cloud ceiling and were provided with spectacular views of periglacial-marine coastal bluffs, periglacial-marine river deltas, oriented lakes, polygonal terrain, streams in the periglacial environment, and pingoes. Photography was hampered during this leg of the flight by persistent cloud cover and the necessity of flying at low altitude. The low altitude also made navigation difficult and caused the aircraft to consume fuel more rapidly than hoped for. Nevertheless, the collective set of cameras recorded many spectacular scenes.

Upon turning south toward Fairbanks, we cruised at high altitude because of low fuel; clouds generally obscured our view, except for some of the highest peaks of the Brooks Range, until we reached the south side of the range; then the sky was partially clear until the aircraft landed in Fairbanks. On this part of the flight, we obtained good views of cirques, arêtes, kettles, and other Pleistocene glacial landforms, cryoplanation terraces, gelifluction or solifluction sheets, periglacial thermokarst thaw basins, and meandering and braided streams (including the Yukon River).

Overflight participants obtained a broad perspective on the physical nature of a classic periglacial terrain on Earth. These experiences no doubt will help shape our expectations and future observations of Mars.

References: [1] Coulter H. W. et al. (1965) Map showing extent of glaciations in Alaska. *1:2,500,000 Misc. Inv. Ser. Map I-415.* U.S. Geological Survey, Washington, D.C. [2] Ferrians O. J. (1965) Permafrost map of Alaska. *1:2,500,000. Misc. Inv. Ser. Map I-445.* U.S. Geological Survey, Washington, D.C. [3] Péwé T. L. and Reger R. D., eds. (1993) *Richardson and Glenn Highways, Alaska: Guidebook to Permafrost and Quaternary Geology.* Fairbanks, Alaska, State of Alaska, Dept. of Natural Resources, Div. of Geological and Geophysical Surveys. 289 pp. [4] Péwé T. L. (1982) *Geologic Hazards of the Fairbanks Area, Alaska.* Special Report 15, State of Alaska, Dept. of Natural Resources, Div. of Geological and Geophysical Surveys. 109 pp.

List of Workshop Participants

Victor R. Baker
Department of Geosciences
University of Arizona
Tucson AZ 85721
Phone: 602-621-6003
Fax: 602-621-2672

Nadine G. Barlow
Lunar and Planetary Institute
3600 Bay Area Boulevard
Houston TX 77058
Phone: 713-280-9021
Fax: 713-480-1279
E-mail: LPI::BARLOW

James E. Begét
Department of Geology and Geophysics
University of Alaska at Fairbanks
Fairbanks AK 99775-1200
Phone: 907-474-5301
Fax: 907-474-5163

Michael H. Carr
Mail Stop 946
U.S. Geological Survey
345 Middlefield Road
Menlo Park CA 94025
Phone: 415-329-5174
Fax: 415-329-4936
E-mail: mcarr@isdmnl.wr.usgs.gov

Mary G. Chapman
U.S. Geological Survey
2255 N. Gemini Drive
Flagstaff AZ 86001
Phone: 602-556-7182
Fax: 602-556-7014

Robert A. Craddock
MRC 315
Center for Earth and Planetary Studies
National Air and Space Museum, Room 3775
Smithsonian Institution
Washington DC 20560
Phone: 202-357-1457
Fax: 202-786-2566
E-mail: craddock@ceps.nasm.edu

Virginia Gulick
Mail Stop 245-3
Space Science Division
NASA Ames Research Center
Moffett Field CA 94035
Phone: 415-604-0781
Fax: 415-604-6779
E-mail: gulick@convx1.ccit.arizona.edu

Dave Hopkins
Department of Geology and Geophysics
University of Alaska
Fairbanks AK 99775-1200
Phone: 907-474-6894

Alan Howard
Department of Environmental Sciences
University of Virginia
Charlottesville VA 22903
Phone: 804-924-0563
Fax: 804-982-2137
E-mail: ahgp@virginia.edu

Bruce Jakosky
Laboratory for Atmospheric and Space Physics
Campus Box 392
University of Colorado
Boulder CO 80309-0392
Phone: 303-492-8004
Fax: 303-492-6946
E-mail: ZODIAC::JAKOSKY

Jeff Kargel
Astrogeology Branch
U.S. Geological Survey
2255 N. Gemini Drive
Flagstaff AZ 86001
Phone: 602-556-7034
Fax: 602-556-7014

Jurgen Kienle
Geophysical Institute
University of Alaska
Fairbanks AK 99775-1200

Baerbel K. Lucchitta
U.S. Geological Survey
2255 North Gemini Drive
Flagstaff AZ 86001
Phone: 602-527-7176
Fax: 602-556-7014

Leonard Martin
Lowell Observatory
1400 West Mars Hill Road
Flagstaff AZ 86001
Phone: 602-774-3358
Fax: 602-774-6296
E-mail: ljm@lowell.edu

George E. McGill
Department of Geology and Geography
University of Massachusetts
Amherst MA 01003
Phone: 413-545-0140
Fax: 413-545-1200
E-mail: gmcgill@wana.geo.umass.edu

Michael Mellon
Laboratory for Atmospheric and Space Physics
Campus Box 392
University of Colorado
Boulder CO 80309-0392
Phone: 303-492-7902
Fax: 303-492-6946
E-mail: mellon@argyre.colorado.edu

Jeff M. Moore
Mail Stop 245-3
Space Sciences Division
NASA Ames Research Center
Moffett Field CA 94035
Phone: 415-604-5529
Fax: 415-604-6779
E-mail: GAL::JMOORE

Timothy Parker
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena CA 91109
Phone: 213-740-5121
Fax: 818-354-0966
E-mail: JPLMW2::TJP342

Troy Péwé
Department of Geological Sciences
Arizona State University
Tempe AZ 85287
Phone: 602-965-5081

Richard Reger
3700 Airport Way
Fairbanks AK 99709

Greta Reynolds
Geophysical Institute
University of Alaska
Fairbanks AK 99775

Martha W. Schaefer
Mail Code 921
NASA Goddard Space Flight Center
Greenbelt MD 20771
Phone: 301-286-7026
Fax: 301-286-1616
E-mail: schaefer@denali.gsfc.nasa.gov

Benjamin C. Schuraytz
Lunar and Planetary Institute
3600 Bay Area Boulevard
Houston TX 77058
Phone: 713-486-2187
Fax: 713-486-2162
E-mail: LPI::SCHURAYTZ

Carol Stoker
Mail Stop 245-3
NASA Ames Research Center
Moffett Field CA 94035
Phone: 415-604-6490
Fax: 415-604-6779
E-mail: stoker@val.arc.nasa.gov

Kenneth Tanaka
U.S. Geological Survey
2255 N. Gemini Dr.
Flagstaff AZ 86001
Phone: 602-527-7208
Fax: 602-556-7014
E-mail: ASTROG::KTANAKA

Don Triplehorn
Geology Department
University of Alaska
Fairbanks AK 99775
Phone: 907-455-6723

Melissa Wenrich
Department of Geology
Arizona State University
Tempe AZ 85287-1404
Phone: 602-965-1790
Fax: 602-965-8102
E-mail: wenrich@esther.la.asu.edu

Frederick R. West
520 Diller Road
Hanover PA 17331-4805
Phone: 717-632-6055

James R. Zimbelman
MRC 315
Center for Earth and Planetary Studies
National Air and Space Museum
Smithsonian Institution
Washington DC 20560
Phone: 202-357-1424
Fax: 202-786-2566
E-mail: jrz@wright.nasm.edu

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